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The Optical Constants of Au and Ag in the Wavelength Range 0.4-2.5 μm

The optical constants n and k of gold and silver have been measured in the wavelength range 0.4–2.5 μm at room temperature, by the usual method of analyzing the intensity and polarization of the monochromatic light reflected by the metallic surface prepared in vacuum of 10^{-5} mm Hg. The measurements have been carried out in air. Values thus obtained are listed and compared with those measured by different authors in vacuum.

1. Introduction

Metals are characterized by two optical quantities, i.e the refractive index n and the absorption coefficient k, which are related to the dielectric constant ε and to the conductivity σ of the metal at the frequency ω, according to Maxwell's relations

$$\varepsilon = n^2 - k^2, \tag{1}$$

$$\frac{4\pi\sigma}{\omega} = 2nk. \tag{2}$$

If monochromatic linearly polarized light with azimuth 45° to the plane of incidence is incident on a metallic surface, the intensity and the polarization of the reflected light is given by Fresnel's equation:

$$\frac{R_{\|}}{R_{\perp}} e^{i\Delta} = \varrho e^{i\Delta} = \tan\psi e^{i\Delta} = -\frac{\cos(\varphi + x^*)}{\cos(\varphi - x^*)}, \tag{3}$$

where $R_{\|}$ and $R_{\perp}$ are reflected amplitudes parallel and normal to the plane of incidence, respectively, Δ is the phase difference between them, φ is the angle of incidence and x^* is the complex angle of refraction.

From equations (1), (2), (3), Drude [1], Price [2] and Beattie [3] deduced the relation between the measured parameters ϱ and Δ of the polarized light reflected elliptically and the optical constants n and k of the metal in different forms. Applying Price's equations:

$$-\varepsilon = k^2 - n^2 = \frac{2\sin^2\varphi\tan^2\varphi(\cos\Delta + \sin 2\psi)}{\sin 2\psi(\cos\Delta + \operatorname{cosec} 2\psi)^2} - \tan^2\varphi, \tag{4}$$

$$\frac{4\pi\sigma}{\omega} = 2nk = \frac{2\sin^2\varphi\tan^2\varphi\sin\Delta}{\tan 2\psi(\cos\Delta + \operatorname{cosec} 2\psi)^2}. \tag{5}$$

In calculating our results we used Crosby's [4] tables, based on the above equations.

2. Experimental method

On the present measurements we have adopted Beattie's method [5], which was applied in case of alkali metals [6–7]. The opaque Au and Ag films are evaporated in vacuum of about 10^{-5} mm Hg, and the measurements were taken in air at room temperature.

The system used is shown in Fig. 1. The plane polarized light, transmitted from the polarizer P which is fixed at azimuth $\psi_p = +\pi/4$ to the plane of incidence, falls on the specimen S at an angle of incidence $\varphi = 80°$. The reflected light, which becomes elliptically polarized, is analyzed by setting the analyzer A at azimuth

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$\psi_A = 0, \pi/2, \pm\pi/4$ and $\mp\pi/4$ giving intensities I_1, I_2, I_3 and I_4, respectively. These intensities are focused on the slit of the monochromator M, where it is chopped by a chopper, detected by

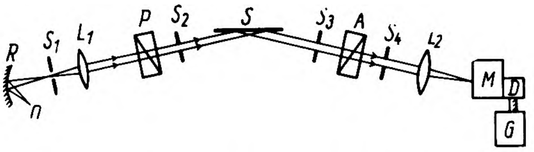

Fig. 1. Apparatus used for the determination of n and k

two detectors D (the photomultiplier from 0.4 to 0.6 μm and the photoconductive cell from 0.6 to 2.5 μm) and amplified by the amplifier G. The monochromator, detector and amplifier are the main parts of the spectrophotometer (Carl Zeiss type PMQII). The polarizer P and the analyzer A are calibrated Nicol prisms (Leybold type).

According to Conn and Eaton [8], the parameters of the reflected ellipse ϱ and Δ can be calculated

$$\varrho = \tan\psi = \tan\psi_P \sqrt{\frac{I_1}{I_2}}, \qquad (6)$$

$$\cos\Delta = \frac{1}{2}\left(\varrho + \frac{1}{\varrho}\right)\frac{I_3 - I_4}{I_3 + I_4}. \qquad (7)$$

Substituting ψ and Δ in equations (4) and (5), we get n and k.

3. Results and discussion

The optical constants n and k of spectroscopically pure gold and silver are given in the following table.

The dependence of the optical constants n and k on the wavelength λ, is shown in Fig. 2 for Au, and in Fig. 3 for Ag; the data of Schulz [9], Meier [10], Dold & Mecke [11], Otter [12] and Irani [13] are given for comparitive reason. It is clear that our results obtained for k agree with those of previous authors, whereas the values of n are somewhat higher than those obtained by Schulz. This may be due to the exposure of the specimen to air, as reported by Philip [14].

Discussion of the present results, in relation to the free electron theory of metals and the electrical properties of Au and Ag, is given in a subsequent communication.

Optical constants of Au and Ag

λ [μm]	Au		Ag	
	n	k	n	k
0.40	1.512	1.917	0.582	1.87
0.45	1.495	1.885	0.616	2.38
0.50	0.868	1.822	0.554	2.80
0.55	0.592	2.345	0.702	3.25
0.60	0.437	2.921	0.411	3.74
0.65	0.432	3.299	0.433	4.10
0.70	0.441	3.693	0.474	4.45
0.75	0.440	4.112	0.531	4.80
0.80	0.441	4.559	0.630	5.16
0.85	0.445	5.031	0.699	5.53
0.90	0.448	5.567	0.663	5.89
0.95	0.453	6.146	0.542	6.24
1.00	0.459	6.398	0.437	6.58
1.05	0.466	6.645	0.424	6.93
1.10	0.494	6.920	0.385	7.32
1.15	0.499	7.198	0.401	7.63
1.20	0.488	7.497	0.407	7.97
1.25	0.496	7.819	0.430	8.33
1.30	0.506	8.101	0.442	8.66
1.35	0.534	8.396	0.368	8.99
1.40	0.537	8.698	0.463	9.35
1.45	0.563	9.014	0.462	9.74
1.50	0.585	9.360	0.440	10.00
1.55	0.602	9.630	0.513	10.40
1.60	0.626	9.902	0.501	10.70
1.65	0.652	10.306	0.530	11.10
1.70	0.684	10.625	0.566	11.50
1.75	0.701	10.918	0.582	11.80
1.80	0.740	11.318	0.572	12.20
1.85	0.761	11.627	0.630	12.50
1.90	0.792	11.941	0.719	12.80
1.95	0.826	12.267	0.813	13.20
2.00	0.848	12.646	0.875	13.50
2.05	0.876	12.965	0.786	13.80
2.10	0.907	13.343	1.040	14.10
2.15	0.945	13.634	0.988	14.40
2.20	0.977	13.989	1.080	14.80
2.25	1.003	14.310	1.300	15.20
2.30	1.053	14.640	1.250	15.60
2.35	–	–	1.110	16.40
2.40	–	–	1.190	16.60
2.45	–	–	1.280	16.80
2.50	–	–	1.500	16.90

Constantes optiques de Au et de Ag dans la gamme d'ondes 0.4–2.5 μm

On a mesuré, à la température ambiante, les constantes optiques n et k de l' or et de l'argent dans la gamme d'ondes 0,4 – 2,5 μm par la méthode usuelle de l'analyse de l'intensité lumineuse et de la polarisation de la lumière monochromatique refléchie par surface métallique sous vide (10^{-5} mm Hg). Les mesures ont

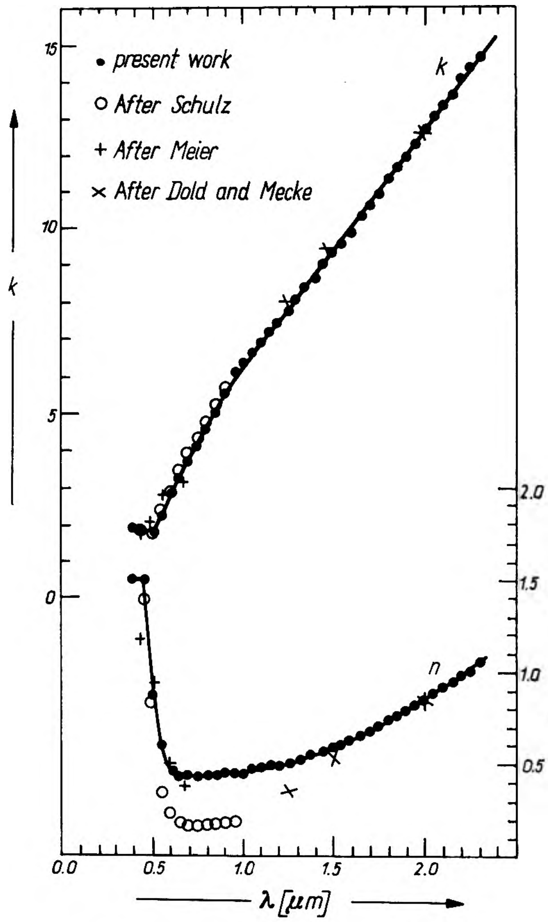

Fig. 2. n and k against λ for Au

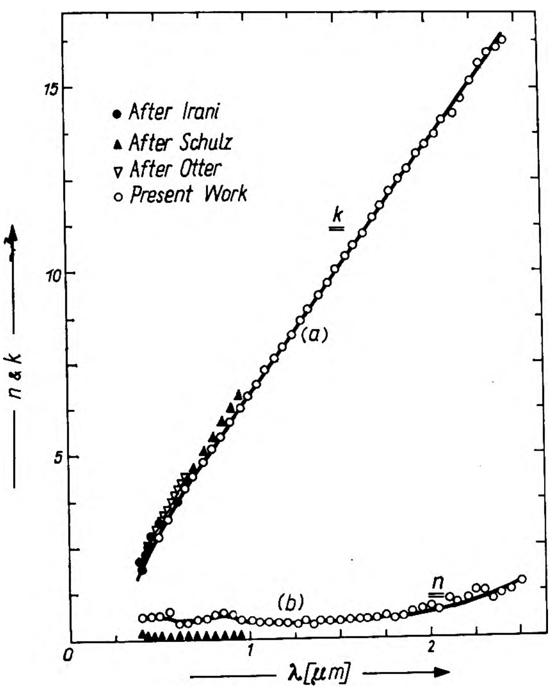

Fig. 3. n and k against λ for Ag

été effectuées dans l'air. On a comparé les données obtenues avec les résultats des mesures faintes sous vide par d'autres chercheurs.

Оптические постоянные Au и Ag в диапазоне волн 0,4—2,5 μm

Оптические постоянные n и k золота и серебра в диапазоне 0,4—2,5 μм измерялись при комнатной температуре, с применением обыкновенного метода анализа интенсивности и поляризации монохроматического света, отраженного от металлической поверхности, изготовленной в вакууме 10^{-5} мм Hg. Измерения проводились на воздухе. Полученные результаты сопоставлены с результатами измерений в вакууме, полученными другими исследователями.

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